Measurement of heavy quarkonia elliptic flow in pPb collisions with the CMS detector

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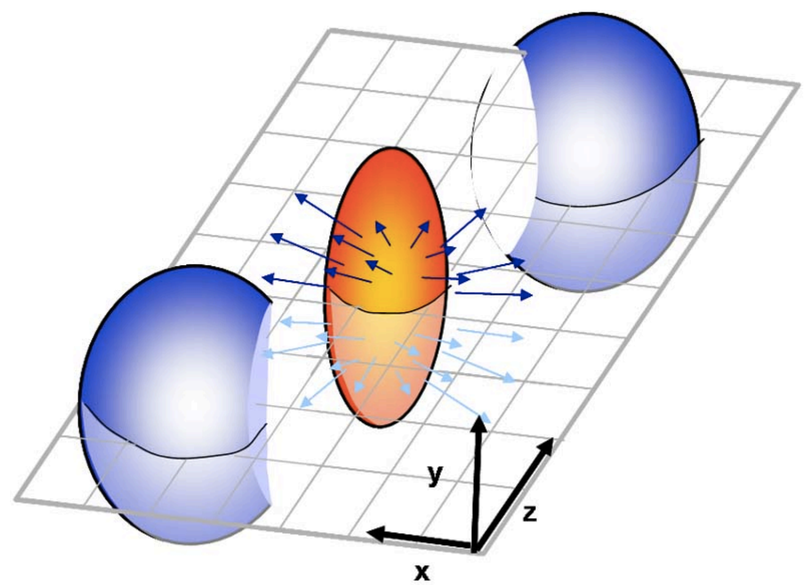
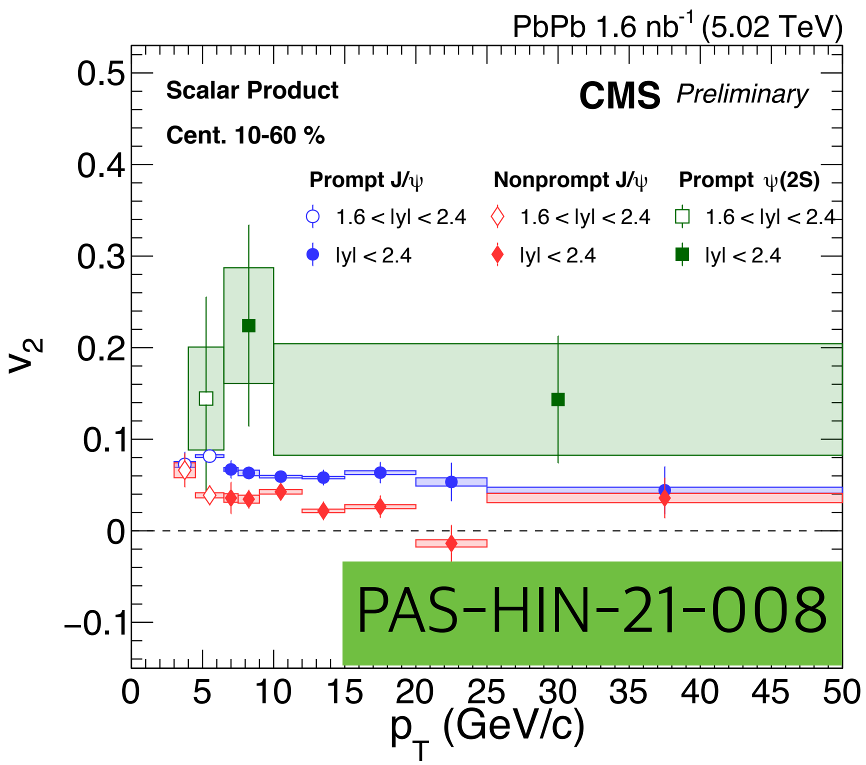
on behalf of the CMS collaboration

March 28th, 2023

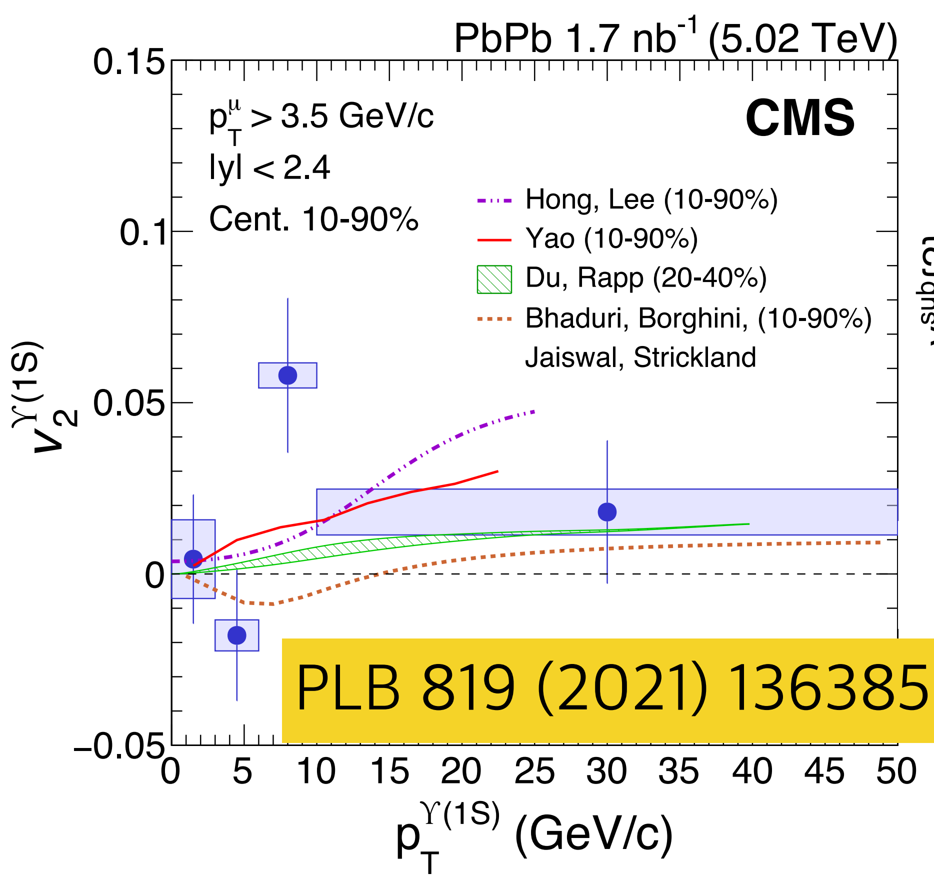
Motivation

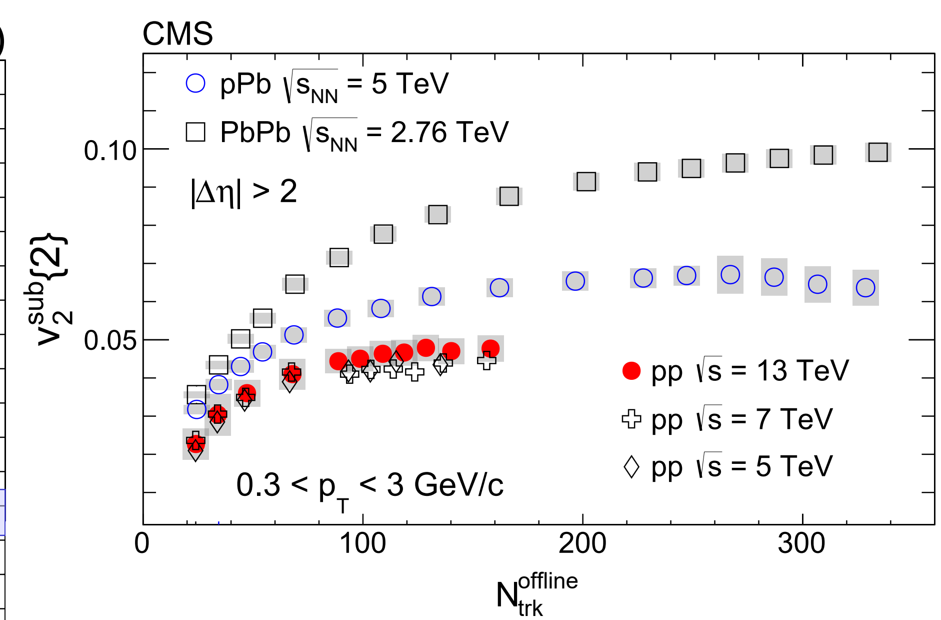
- v_2 of quarkonia is useful tool to study the path-length dependent modification effect and collectivity of heavy flavors
- Large v_2 of J/ψ at low-p_T from recombination effect while v_2 is zero for ϒ(1S) in PbPb
- v_2 of charged particle in small system is not zero in high multiplicity





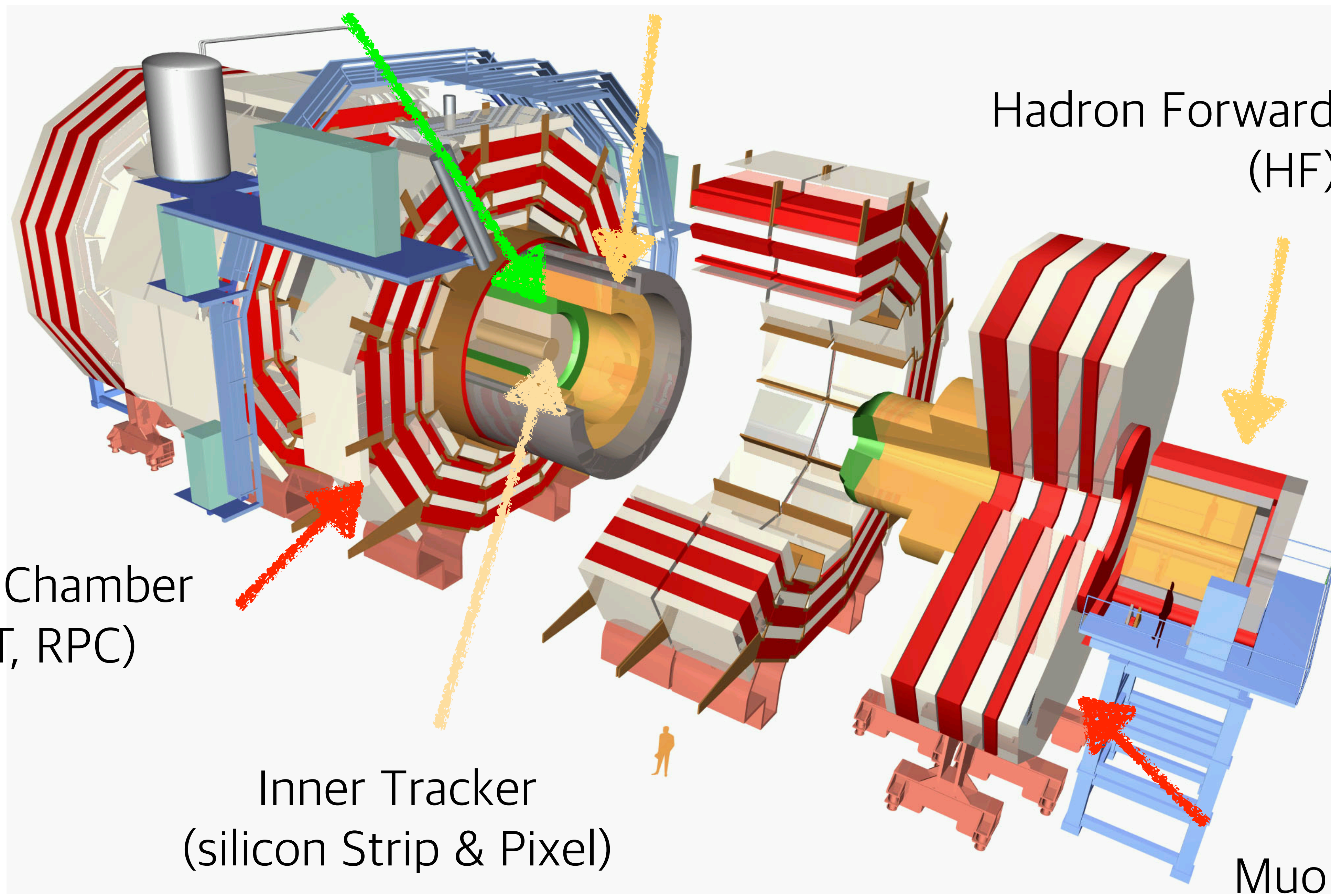
CMS talk by Geonhee Oh
28 March 2023, 11:50



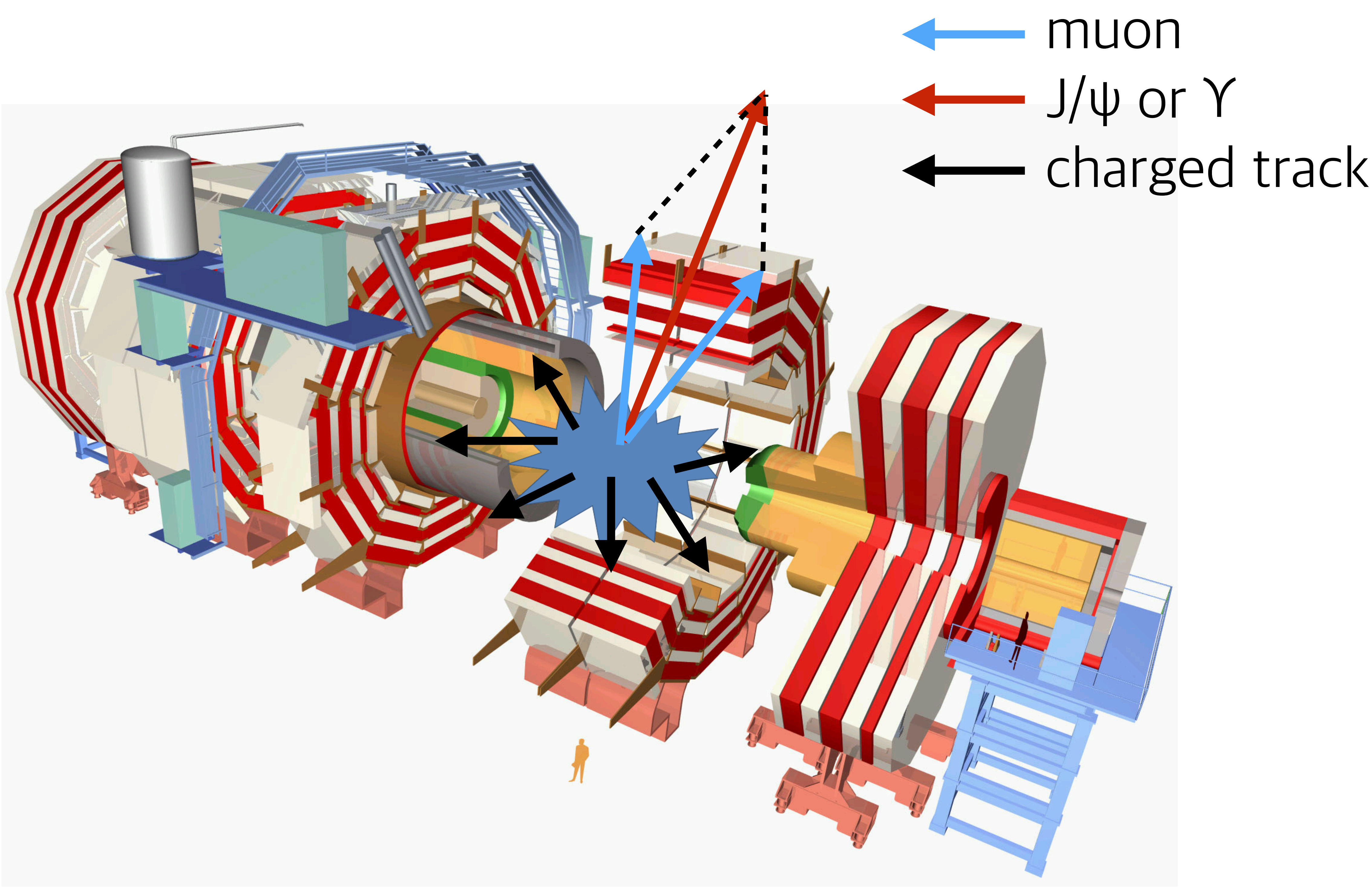


PLB 765 (2017) 193

CMS detector



Particle Reconstruction

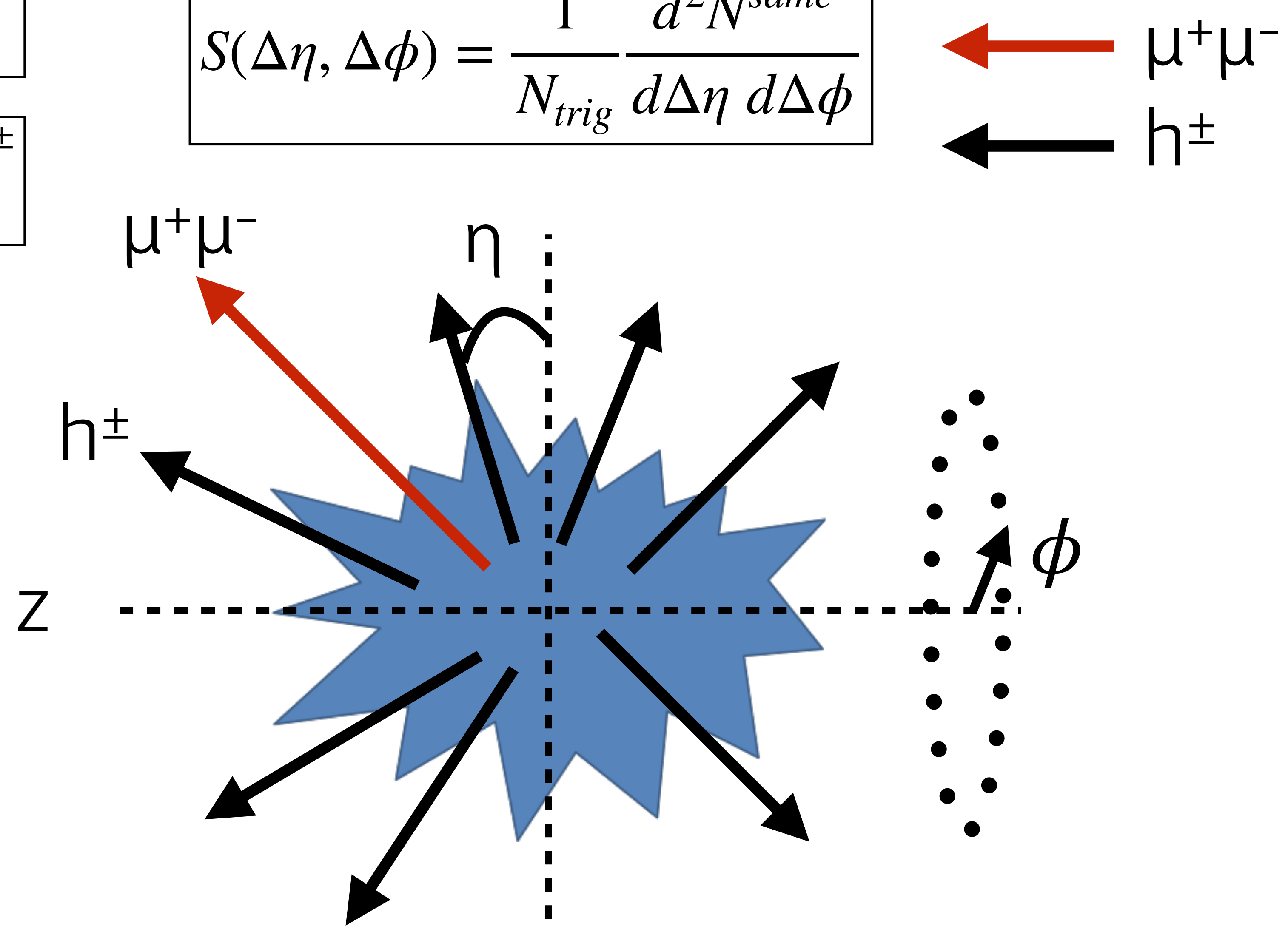


Same event correlation

$$\Delta\eta = \eta^{\mu^+\mu^-} - \eta^{h^\pm}$$

$$\Delta\phi = \phi^{\mu^+\mu^-} - \phi^{h^\pm}$$

$$S(\Delta\eta, \Delta\phi) = \frac{1}{N_{trig}} \frac{d^2N^{same}}{d\Delta\eta\, d\Delta\phi}$$



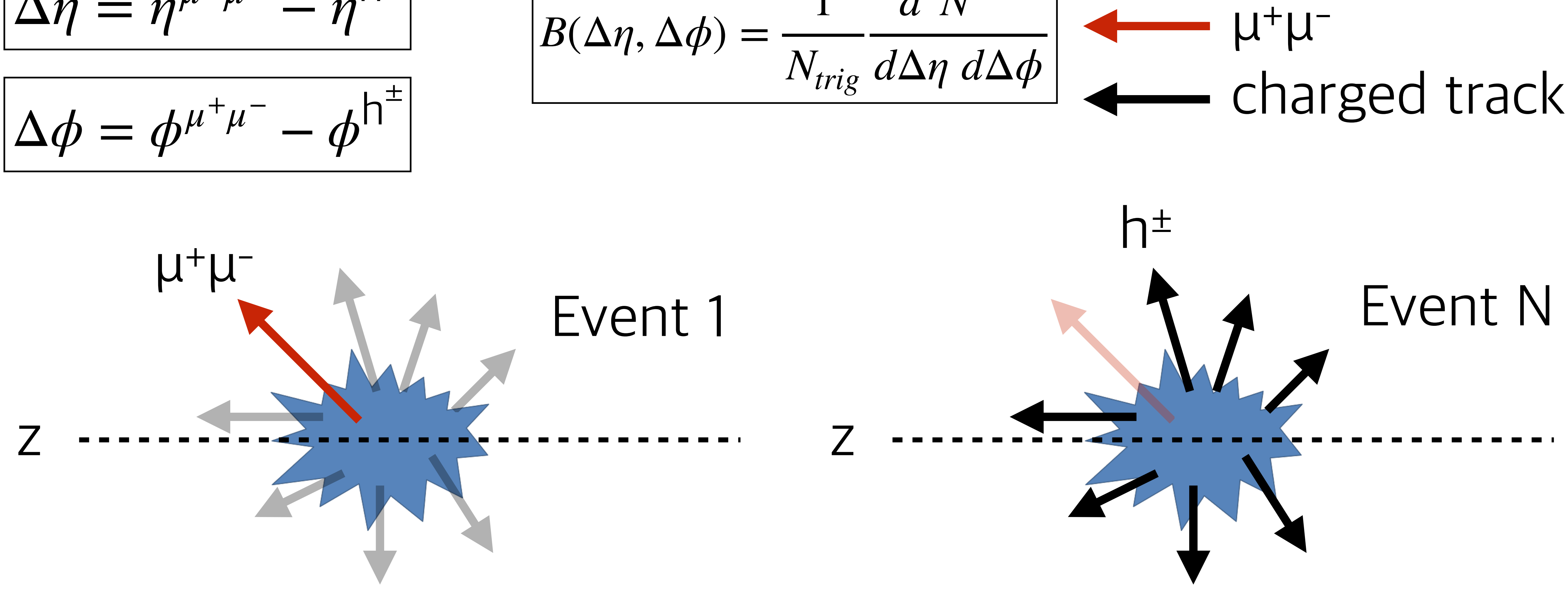
- Two-particle correlations in $\Delta\eta$-$\Delta\phi$
- Trigger particle $\mu^+\mu^-$, associated particle $h^\pm$
- $0.3 < p_T^{track} < 3$ GeV/c

Mixed event correlation

$$\Delta\eta = \eta^{\mu^+\mu^-} - \eta^{h^\pm}$$

$$\Delta\phi = \phi^{\mu^+\mu^-} - \phi^{h^\pm}$$

$$B(\Delta\eta, \Delta\phi) = \frac{1}{N_{trig}} \frac{d^2N^{mix}}{d\Delta\eta\, d\Delta\phi}$$



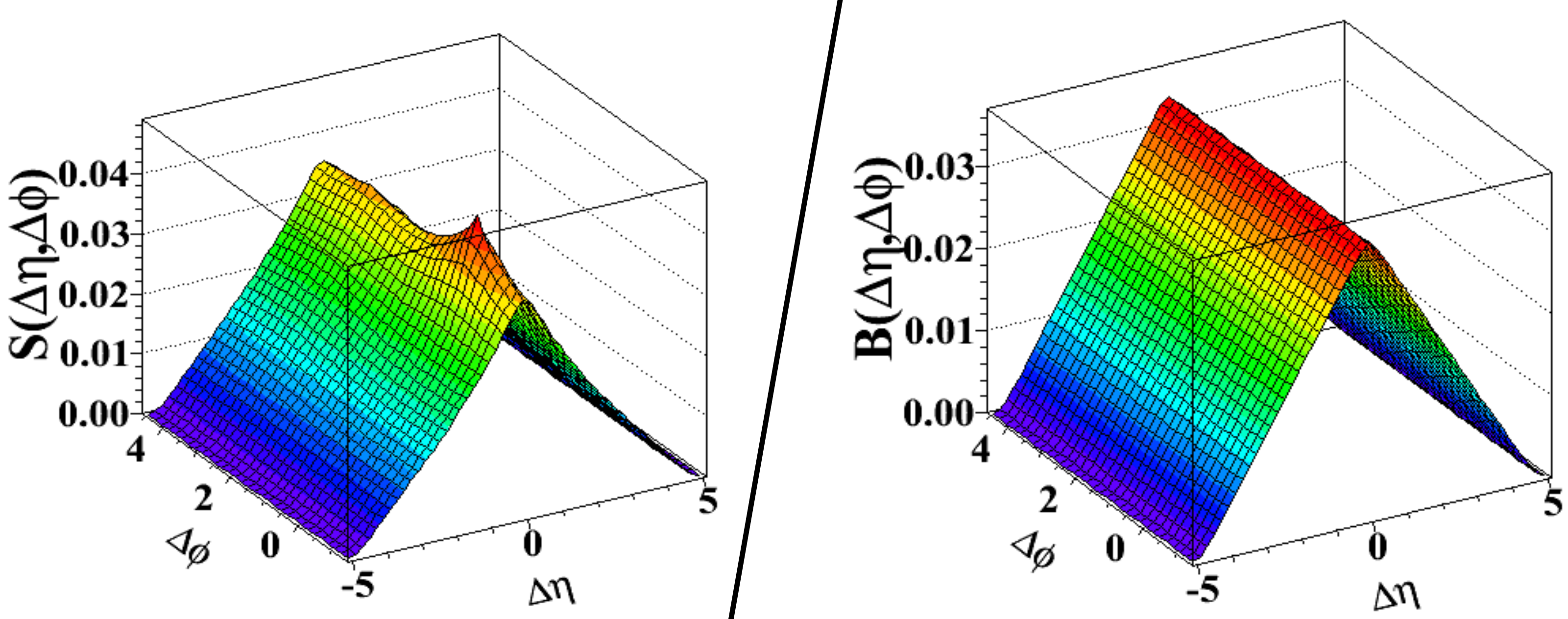
- The di-muon as trigger particle correlated with the charged track associators from the different event
- Random event mixed within $|z_{vtx}^1 - z_{vtx}^2| < 2$ cm

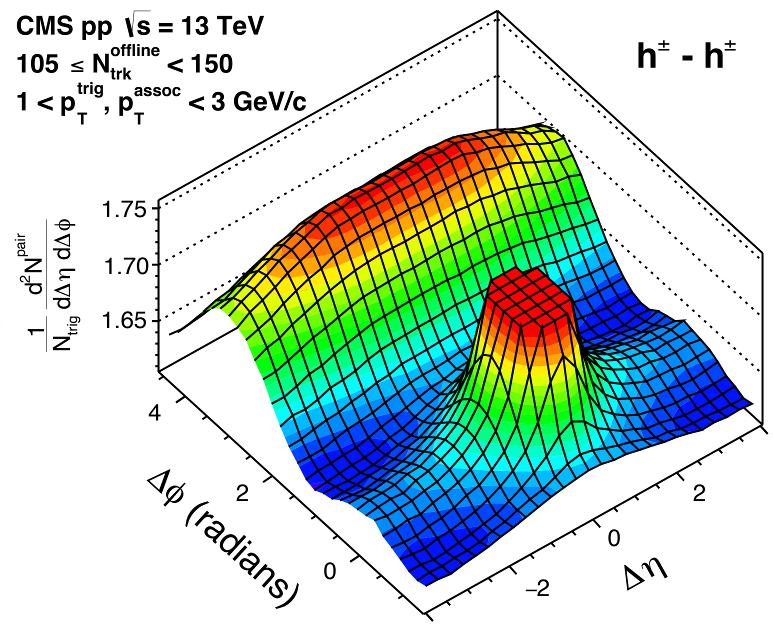
Two-particle correlation method

$$S(\Delta\eta, \Delta\phi) = \frac{1}{N_{trig}} \frac{d^2N^{same}}{d\Delta\eta\, d\Delta\phi}$$

$$B(\Delta\eta, \Delta\phi) = \frac{1}{N_{trig}} \frac{d^2N^{mix}}{d\Delta\eta\, d\Delta\phi}$$

$$\frac{1}{N_{trig}} \frac{d^2N^{pair}}{d\Delta\eta\, d\Delta\phi} = B(0,0) \times \frac{S(\Delta\eta, \Delta\phi)}{B(\Delta\eta, \Delta\phi)}$$





PLB 765 (2017) 193

- Cancel out the random combinatorial background and acceptance effects

Observed V_2 extraction

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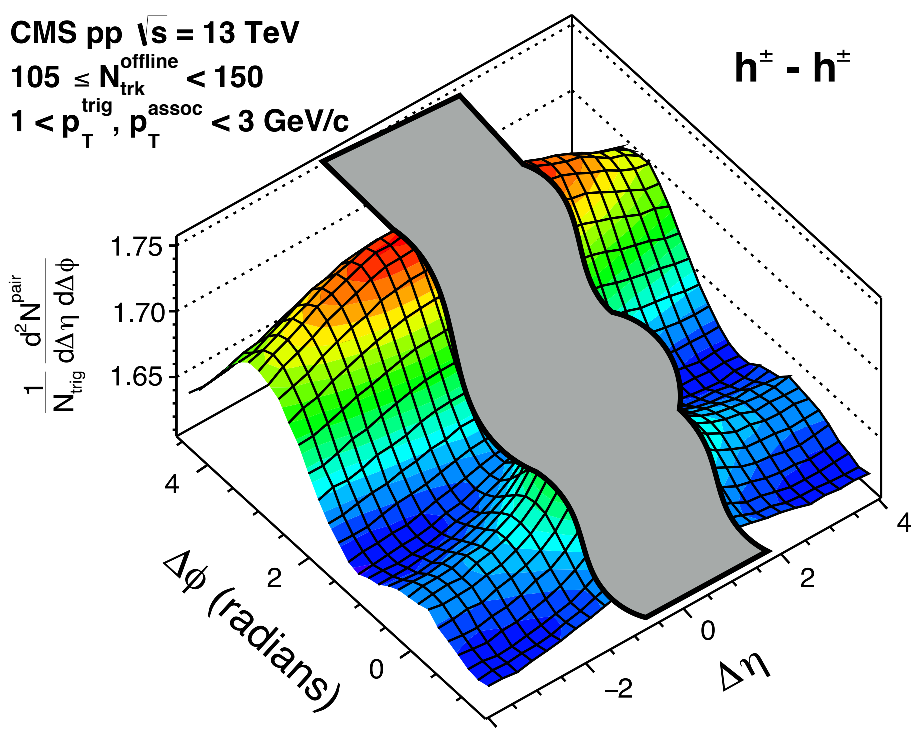

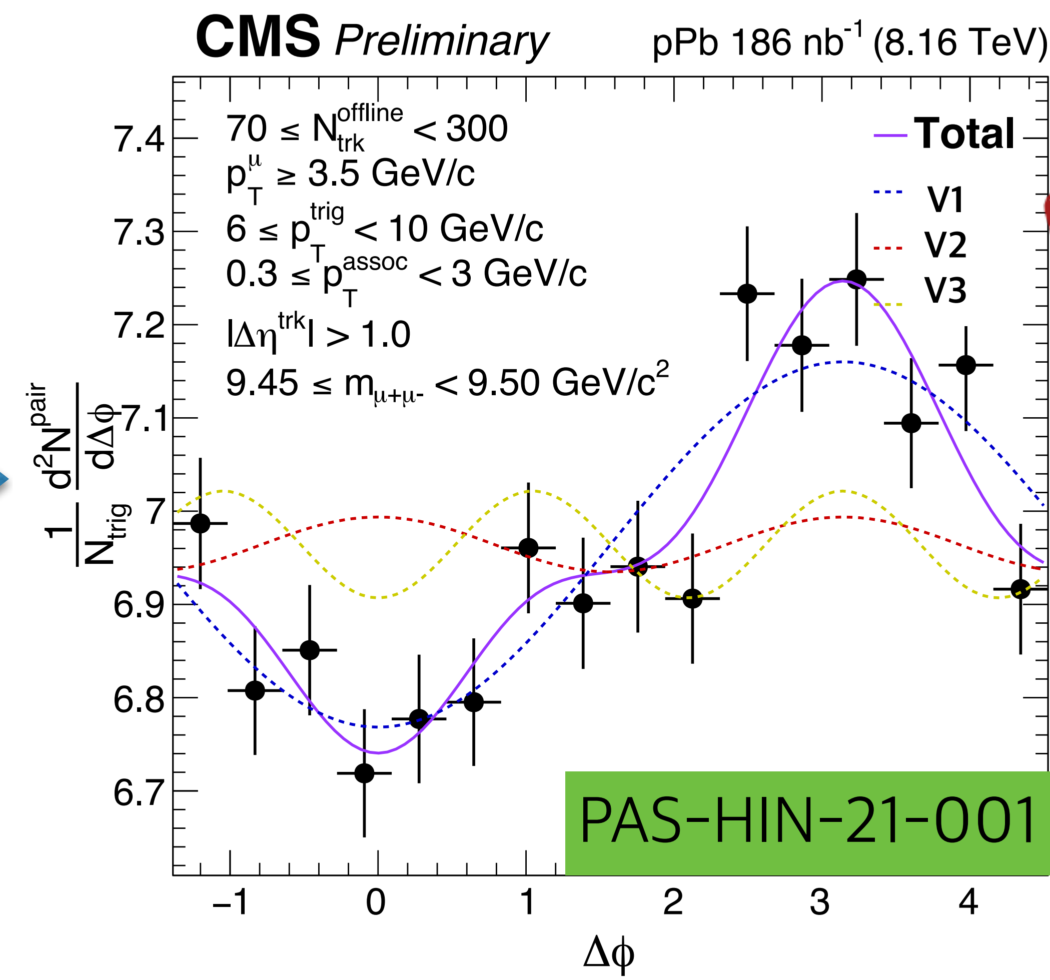

- Long-range (|Δη| > 1) events projected to $\Delta\phi$ axis in order to reject jet contribution

- $V_n([\mu^+\mu^-]+\text{trk})$ is determined from a Fourier decomposition

$$\frac{1}{N_{\text{trig}}}\frac{d^2N^{\text{pair}}}{d\Delta\eta\,\Delta\phi} = \frac{N_{\text{assoc}}}{2\pi}\left\{1 + \sum_n 2V_{n\Delta}\cos(n\Delta\phi)\right\}$$

V_n: $[\mu^+\mu^-]+h^\pm$
v_n: $\mu^+\mu^-$

Simultaneous fitting

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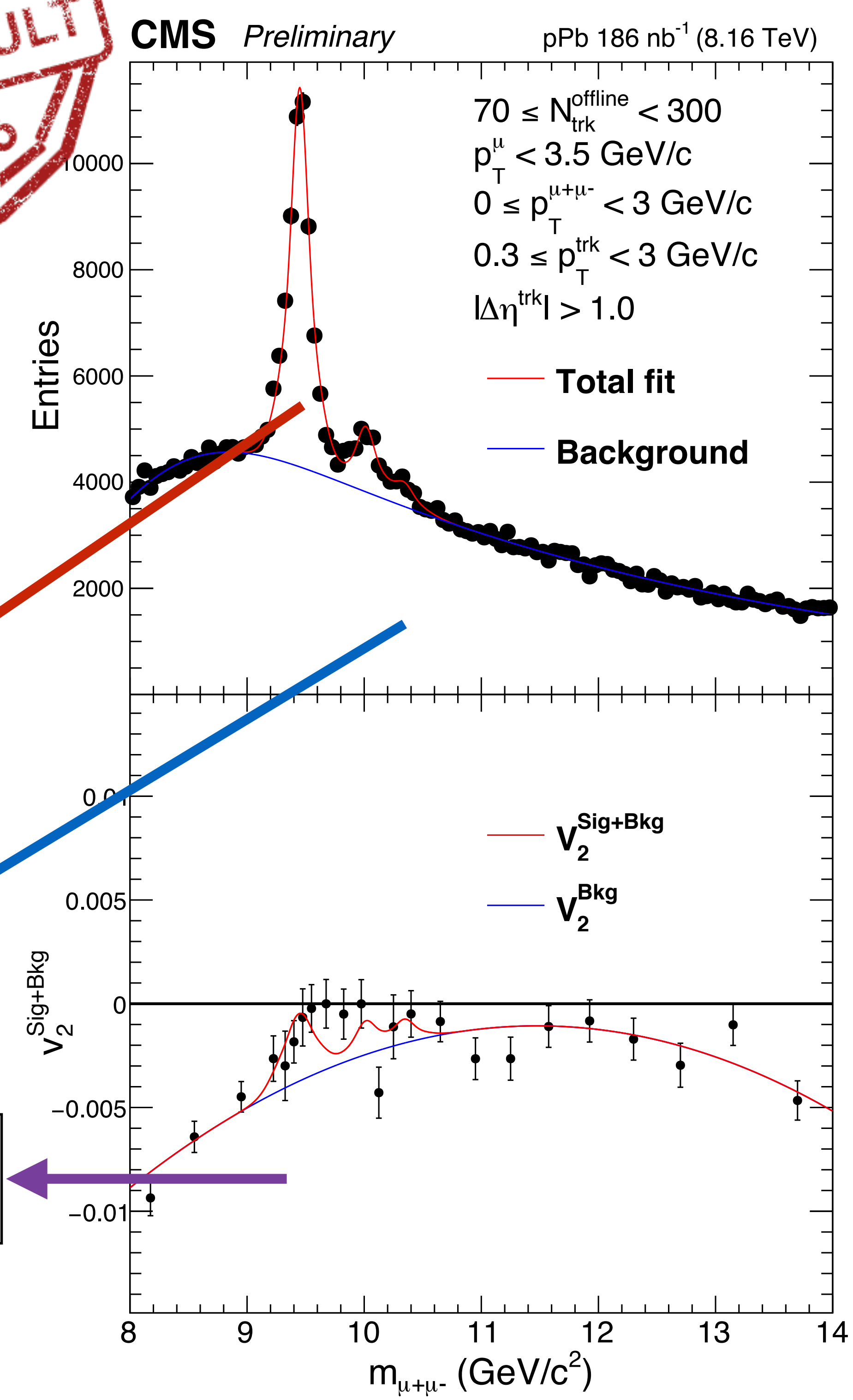
- Observed V_2 is composed of signal-track correlation and background-track correlation
- To extract signal V_2, simultaneous fitting with mass is applied

$$f_{\text{sig}} = \frac{\text{signal}}{\text{signal+background}}$$

$$V_2^{S+B}(m_{\mu+\mu-}) = f_{\text{sig}} V_2^{\text{sig}} + (1 - f_{\text{sig}}) V_2^{\text{bkg}}(m_{\mu+\mu-})$$

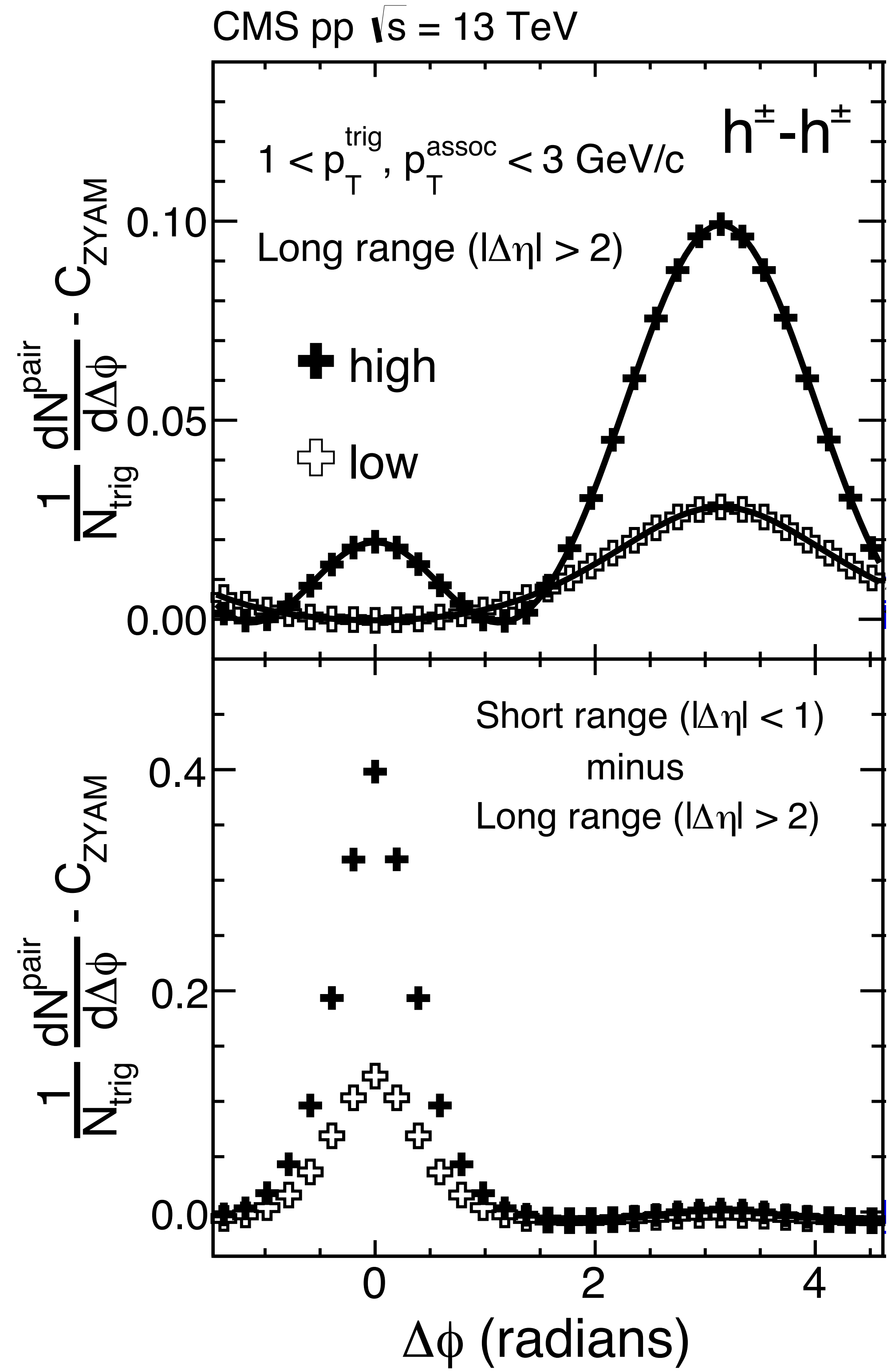


Non-flow subtractions

PLB 765 (2017) 193

- Low-multiplicity subtraction to remove non-flow effect (mostly from back-to-back jet correlation)
- Jet yield ratio used to account for the enhanced jet correlations from low to high-multiplicity

$$V_2^{sub} = V_2^{Sig}(high) - V_2^{Sig}(low) \times \frac{N_{assoc}(low)}{N_{assoc}(high)} \times \frac{J_{jet}(high)}{J_{jet}(low)}$$



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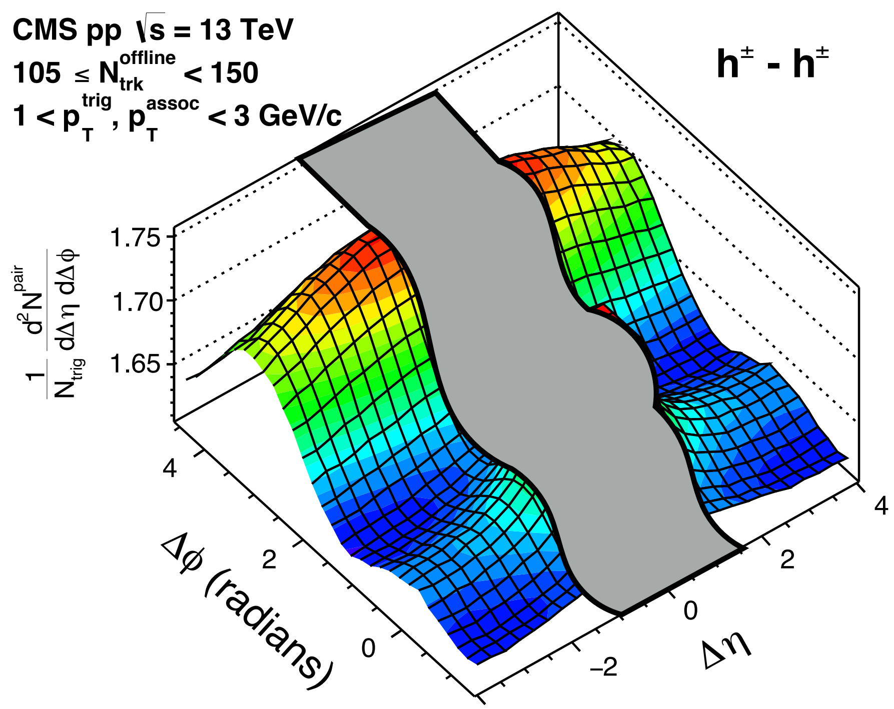

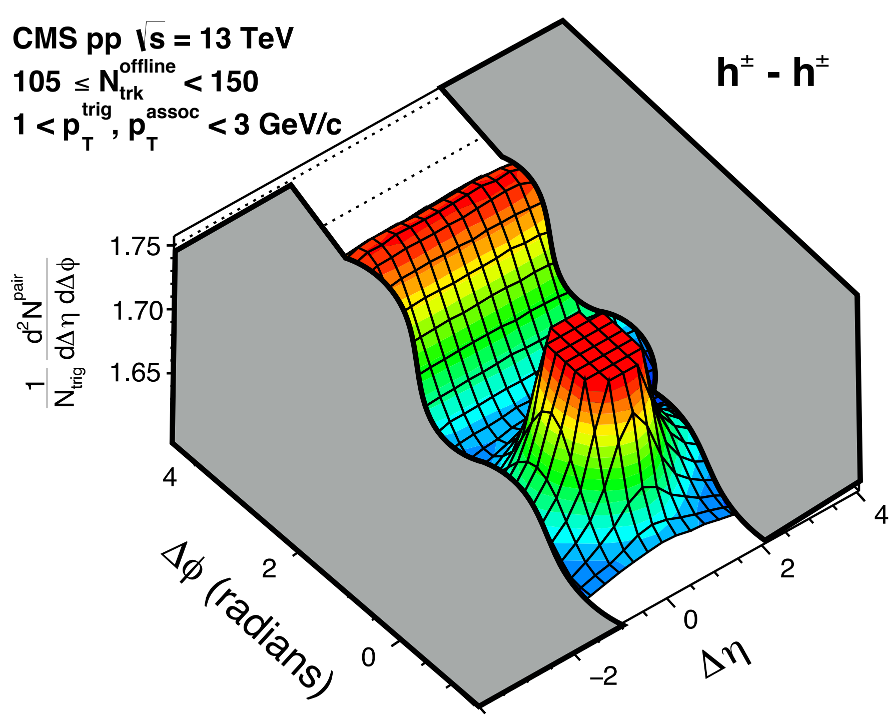

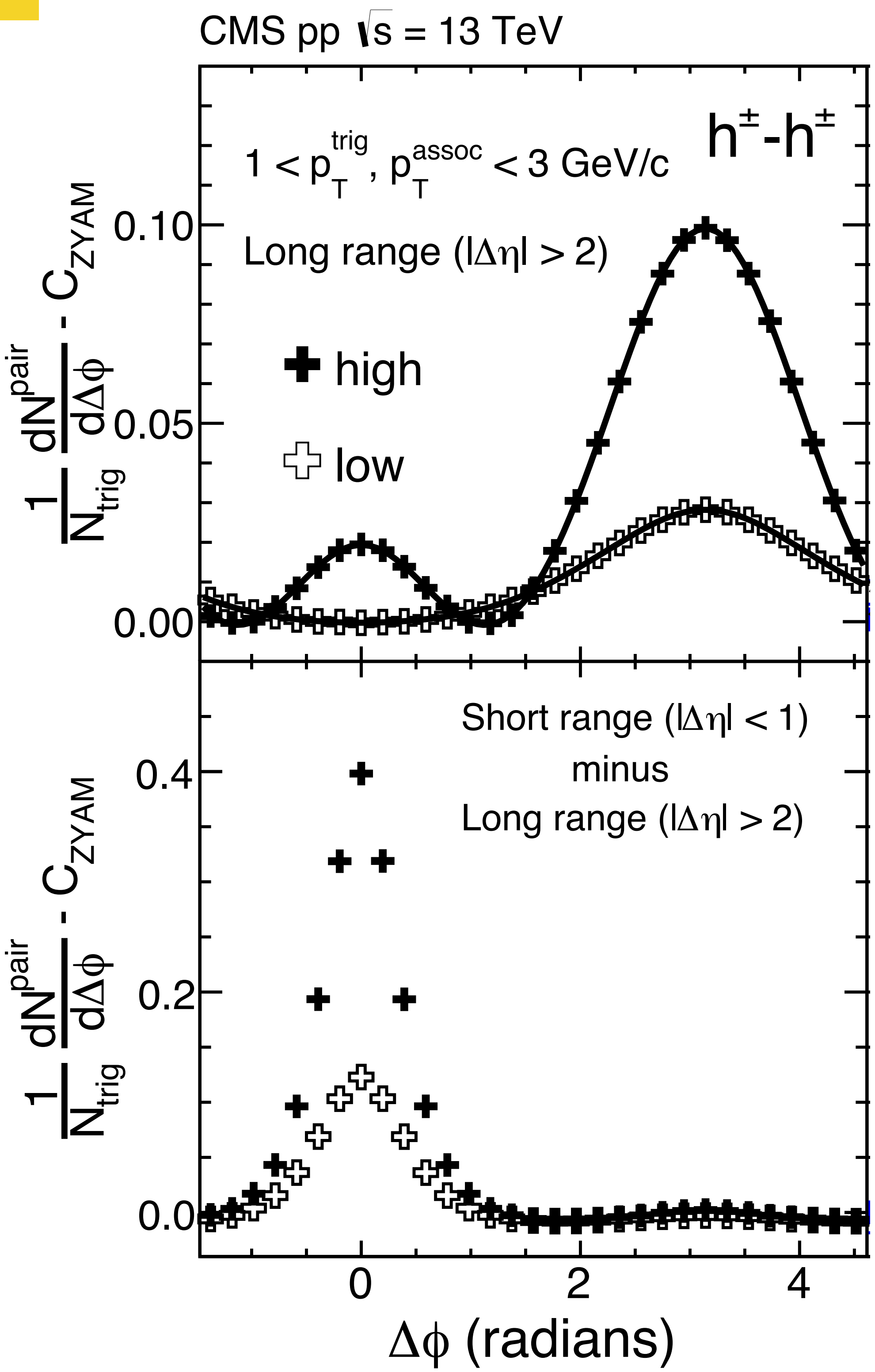

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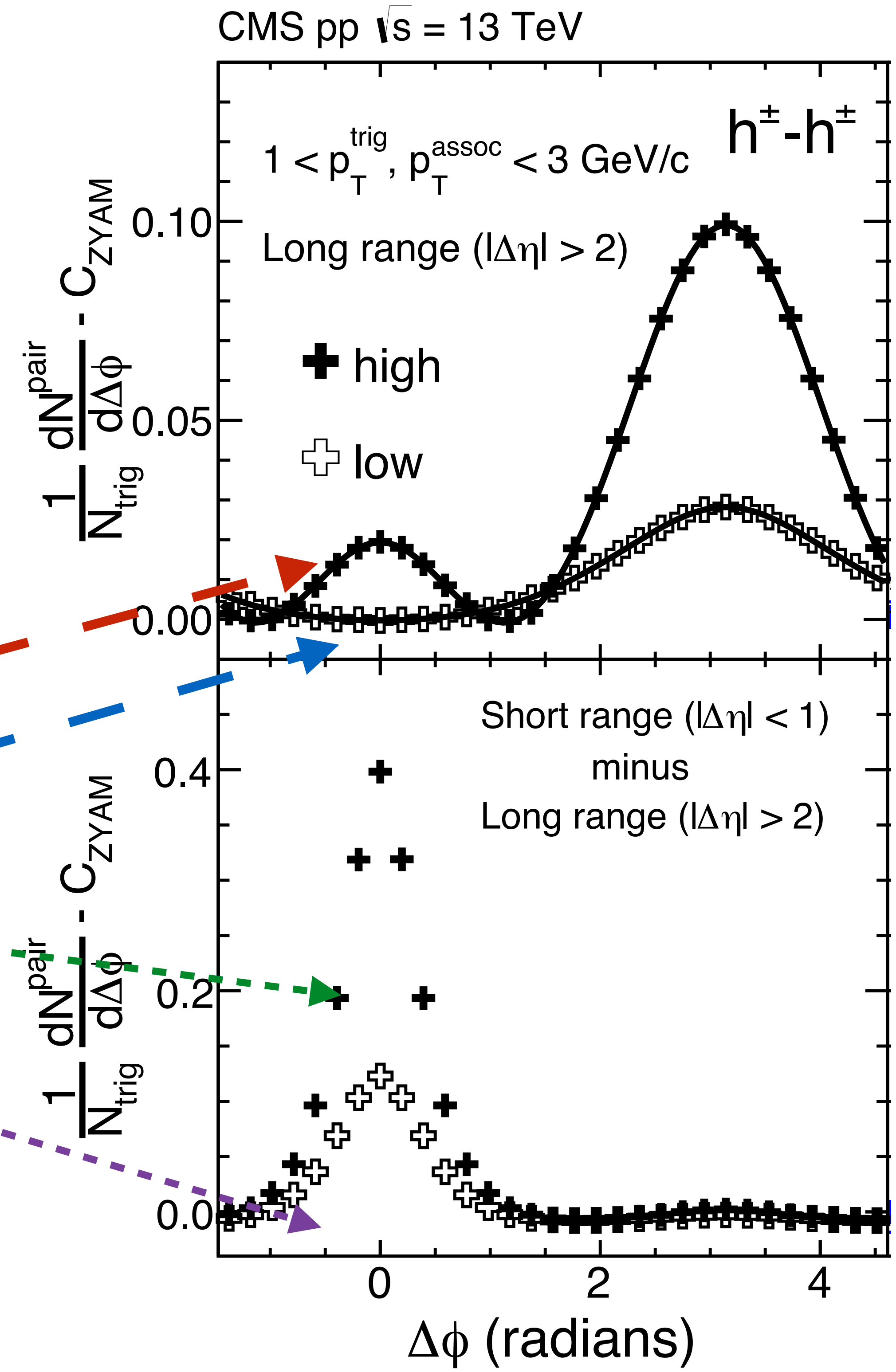
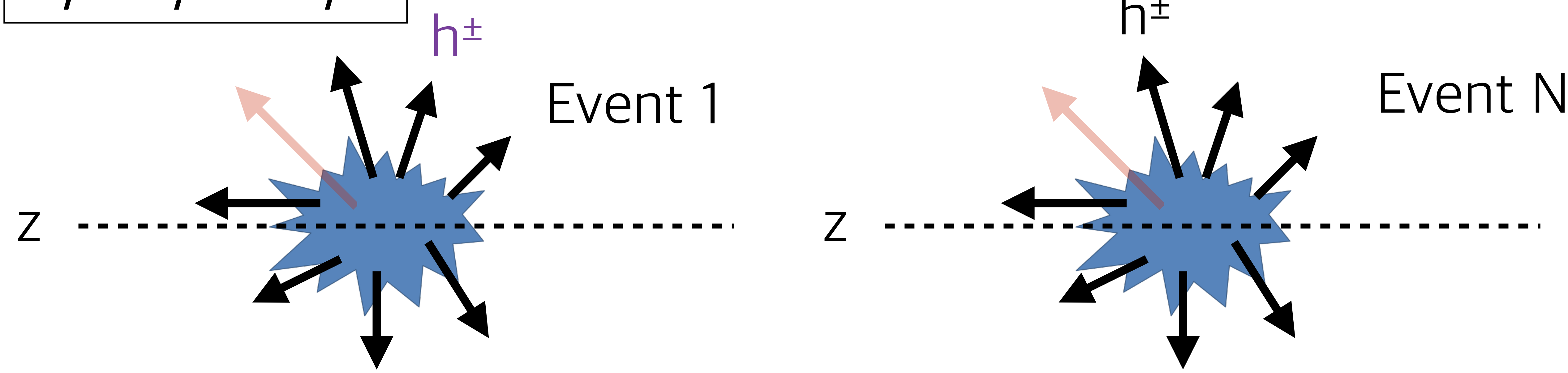


Track V_2 subtractions

$$\Delta\eta = \eta^{h^{\pm}} - \eta^{h^{\pm}}$$

$$\Delta\phi = \phi^{h^{\pm}} - \phi^{h^{\pm}}$$



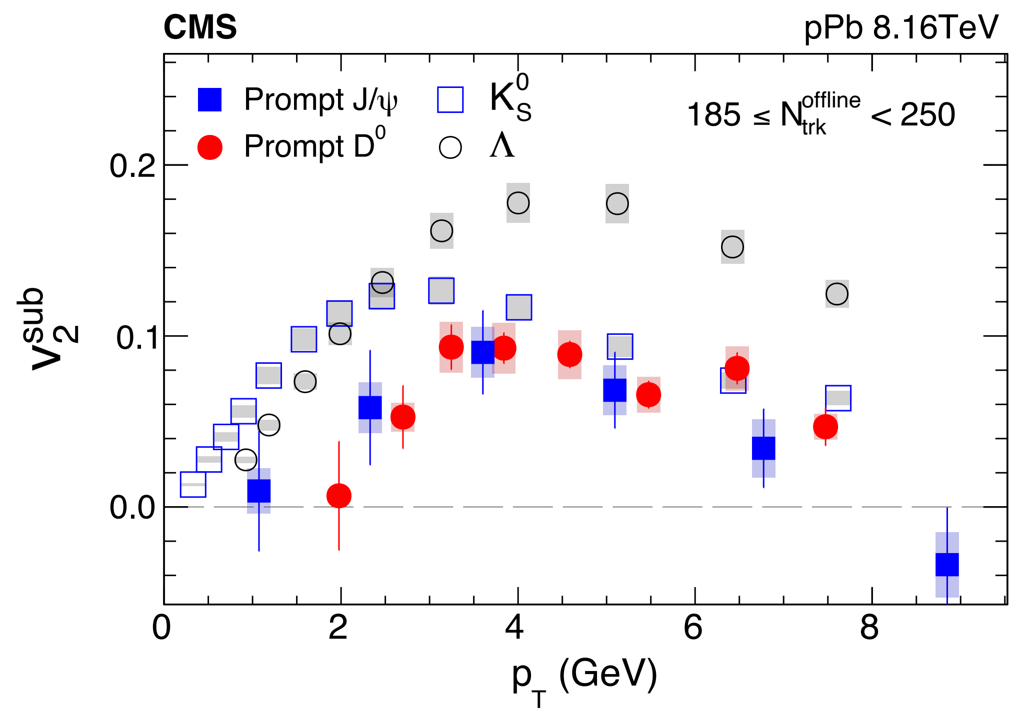
$$v_2^{sub} = \frac{V_2^{sub}}{\sqrt{V_2^{sub(h^{\pm})}}}$$

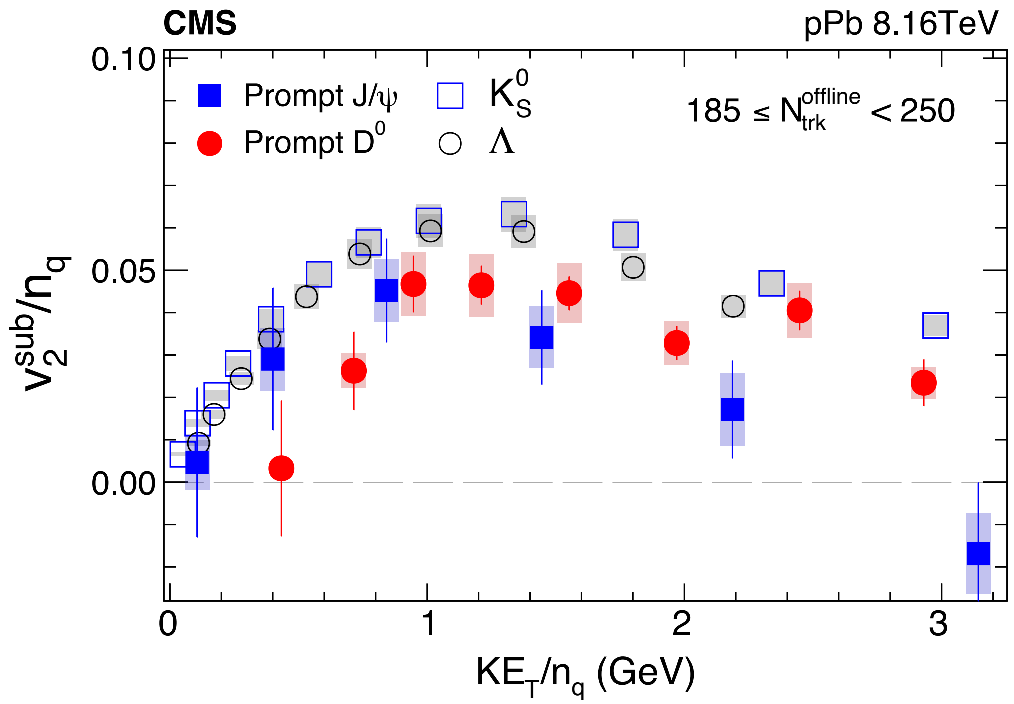
- To extract pure $\mu^+\mu^-$ v_2, track v_2 is divided from the $[\mu^+\mu^-]$+$h^{\pm}$ v_2

Result (pPb J/ψ)

PLB 791 (2019) 172

- Non-zero J/ψ v_2 observed in forward rapidity of high-multiplicity pPb system
- Similar trend between J/ψ(closed charm) and D^0(open charm)
- Smaller than K^0_S and Λ (open strange)
- Weaker collective behavior than light quarks in small systems





Result (pPb Υ)

arXiv 2209.12303

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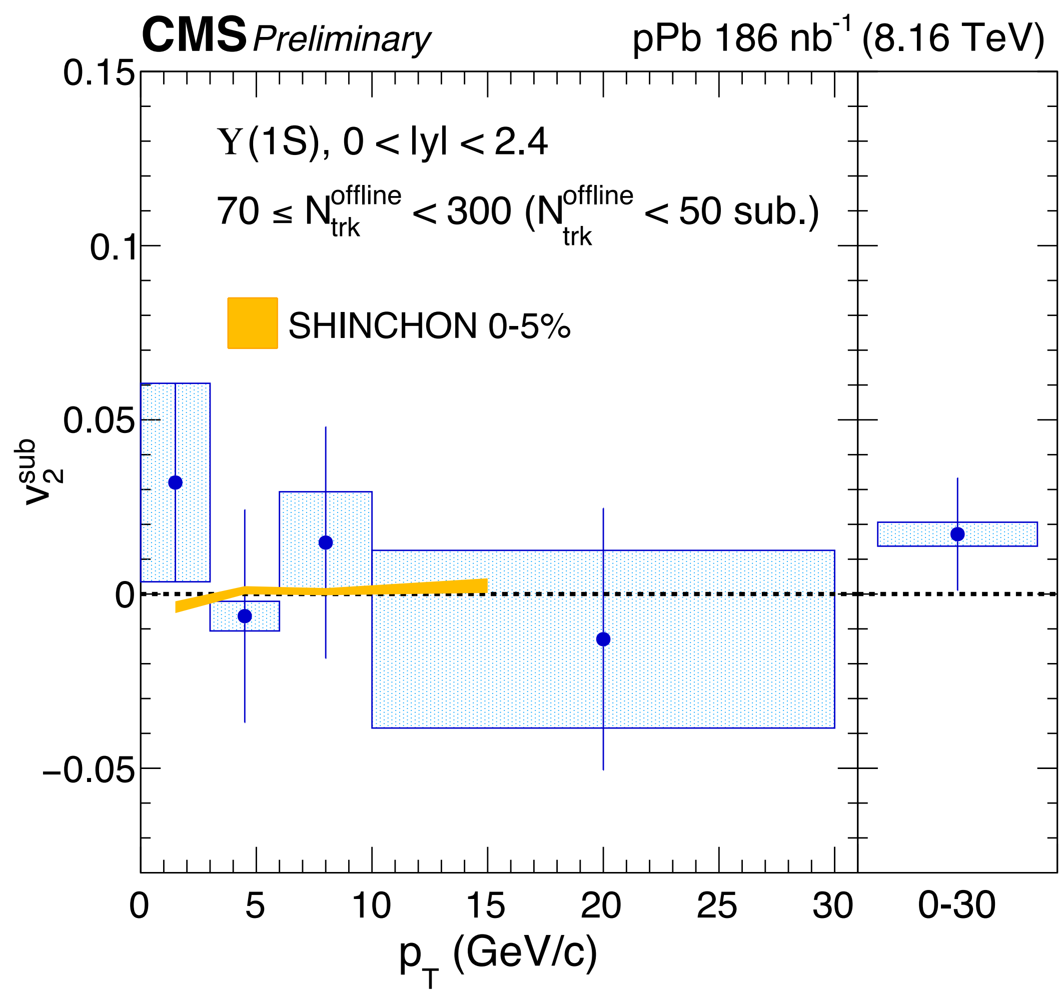

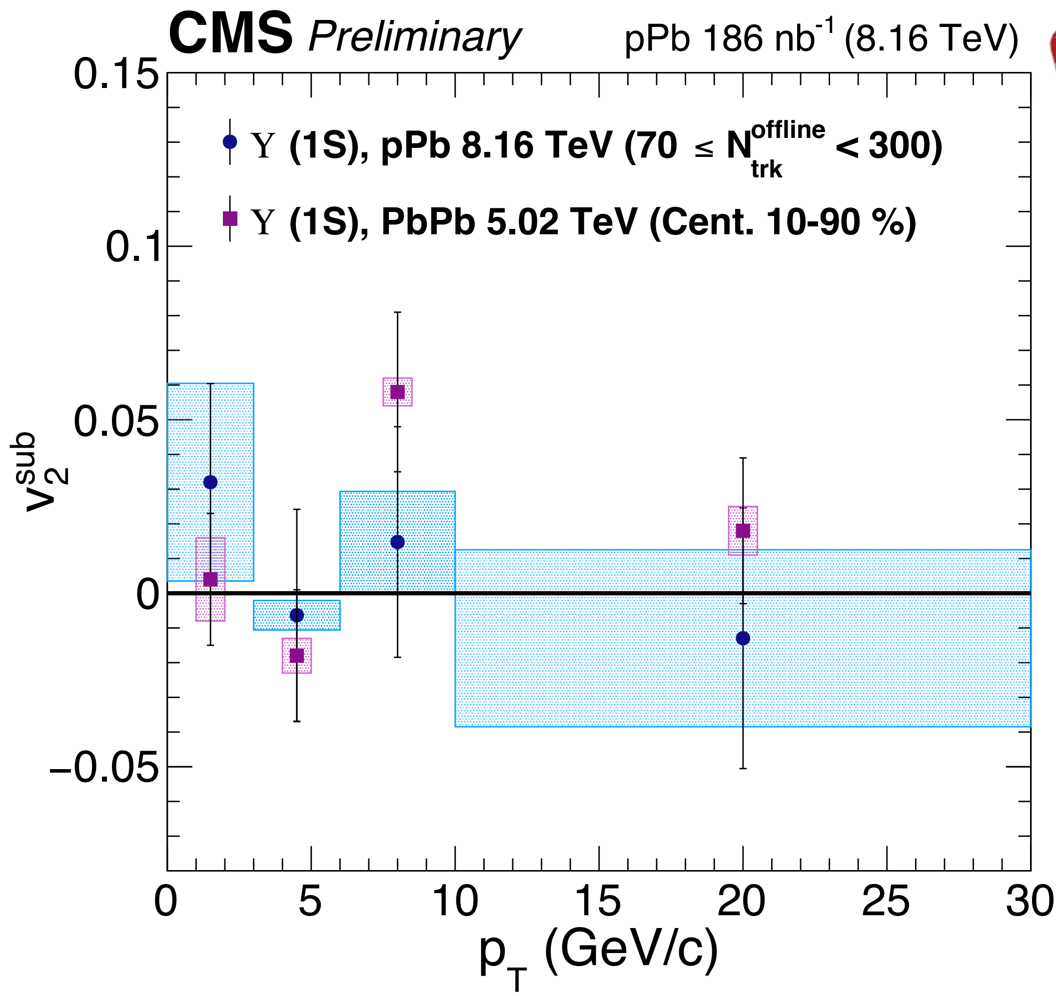

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- Υ(1S) v_2 is consistent with Bolzmann equation using pNRQCD limit
  - Consider medium response on thermal widths (No regeneration)
- Υ(1S) v_2 is consistent with zero regardless of the system size

Result (comparison)

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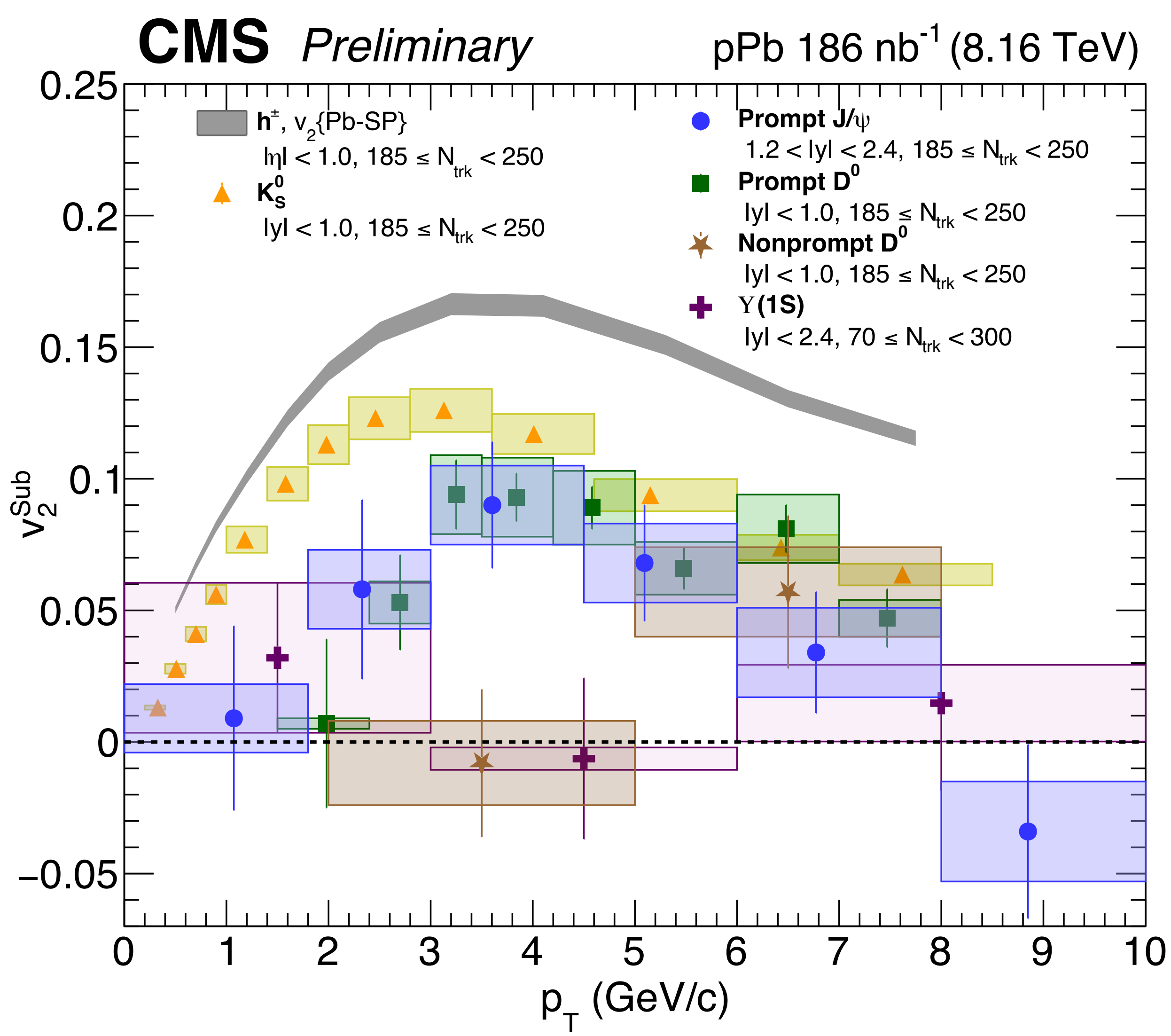

- Compared with different particles
- Not ignorable difference at mid-p_T

Summary

- v_2 of quarkonia is useful tool to study the path-length dependent modification effect and collectivity of heavy flavors
- Weaker collective behavior than light quarks in small systems
- Υ(1S) v_2 measured for the first time in pPb
- Υ(1S) v_2 is close to zero regardless of the system size
- Hint of different behavior for charmonia and bottomonia

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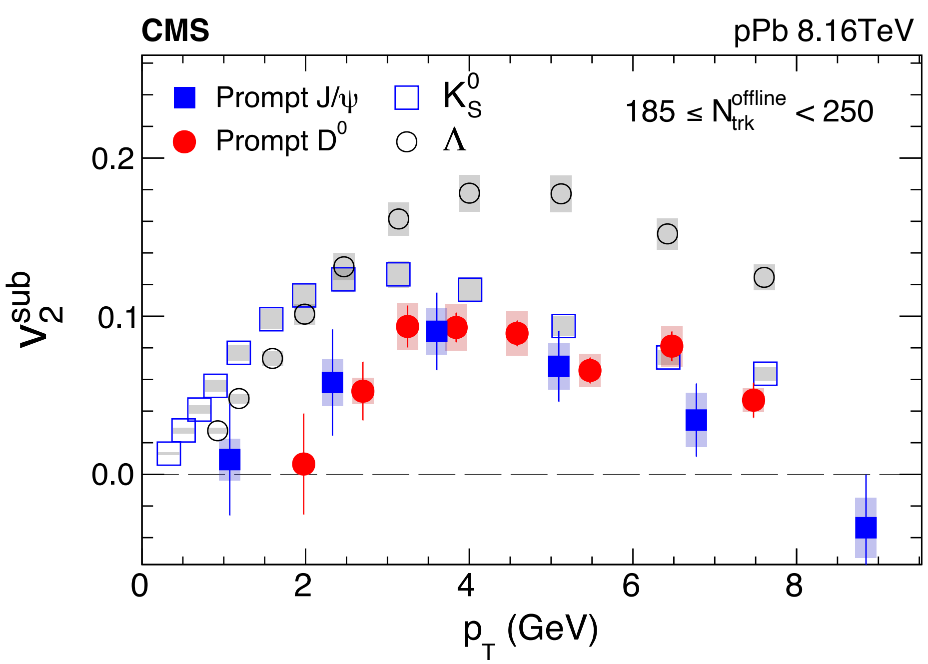
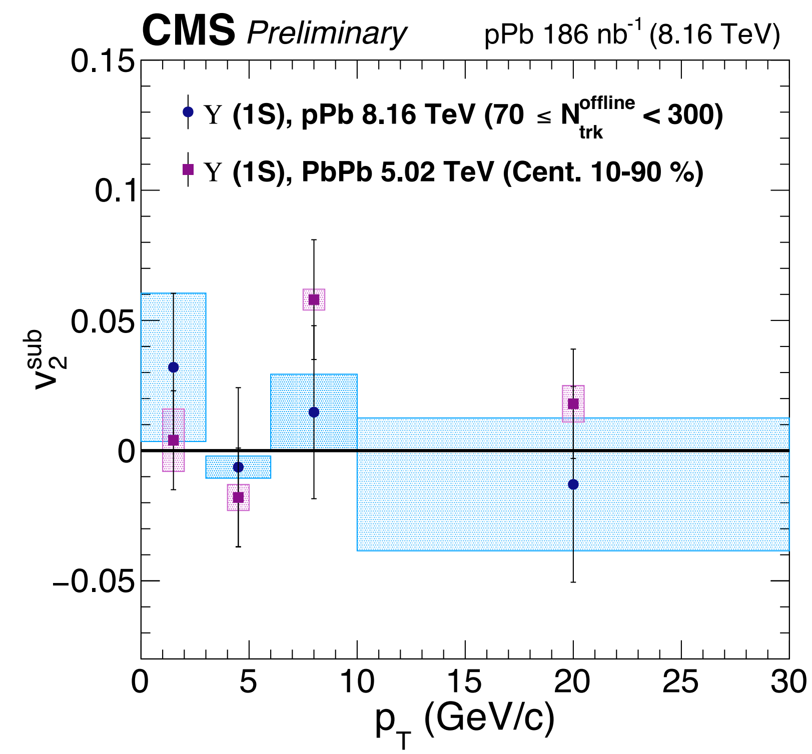
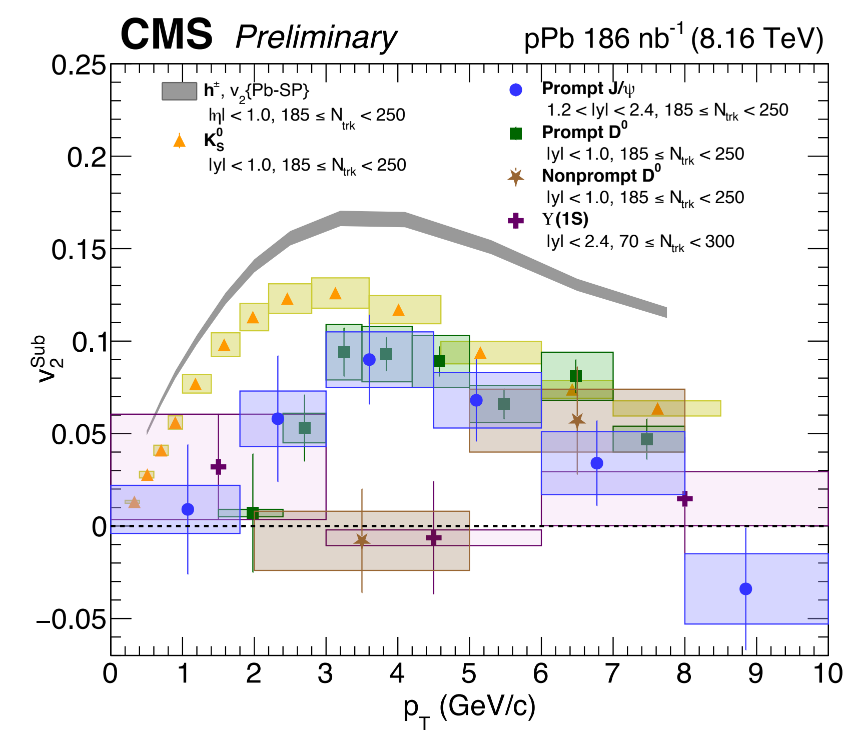
PLB 791 (2019) 172



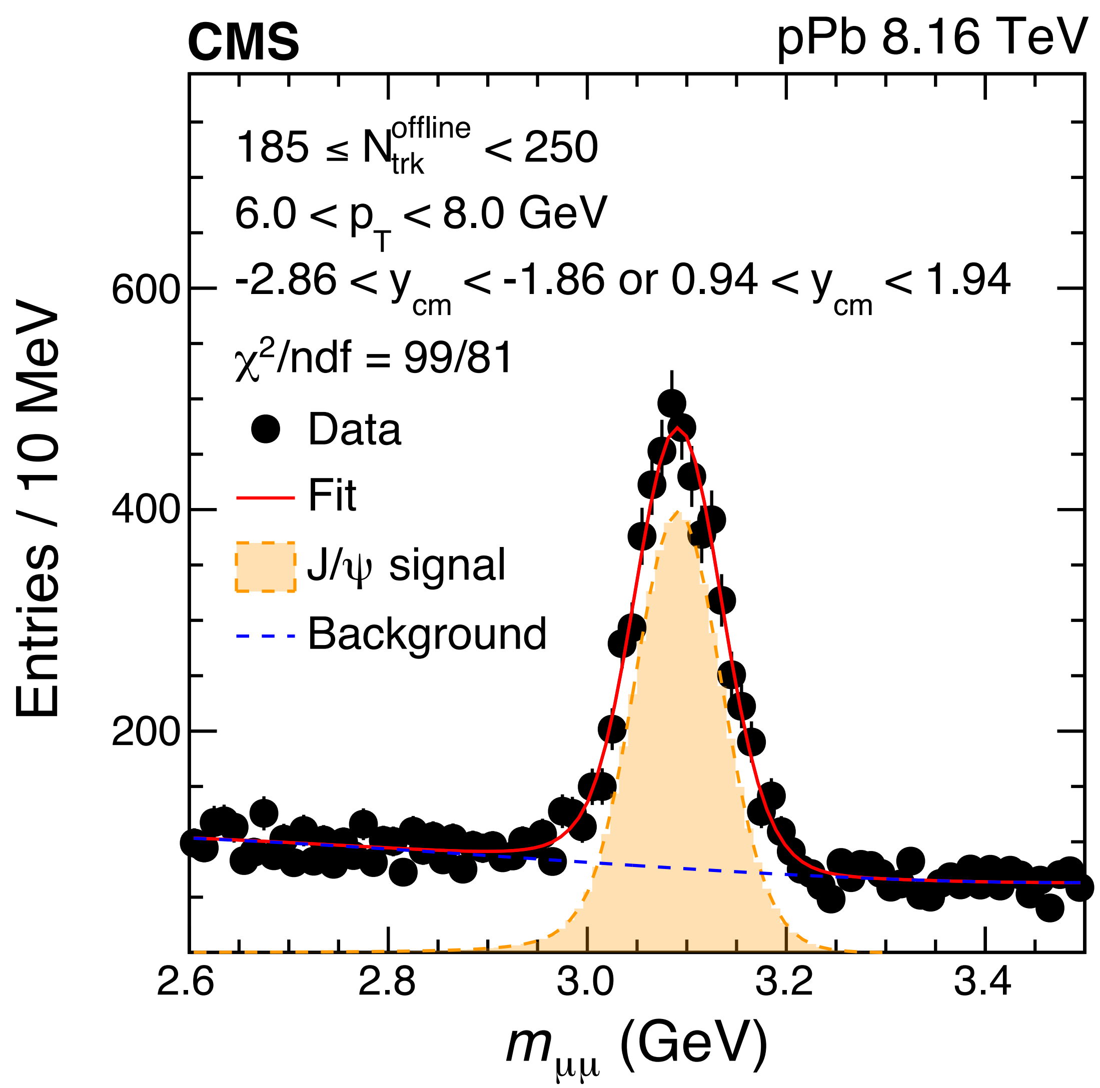


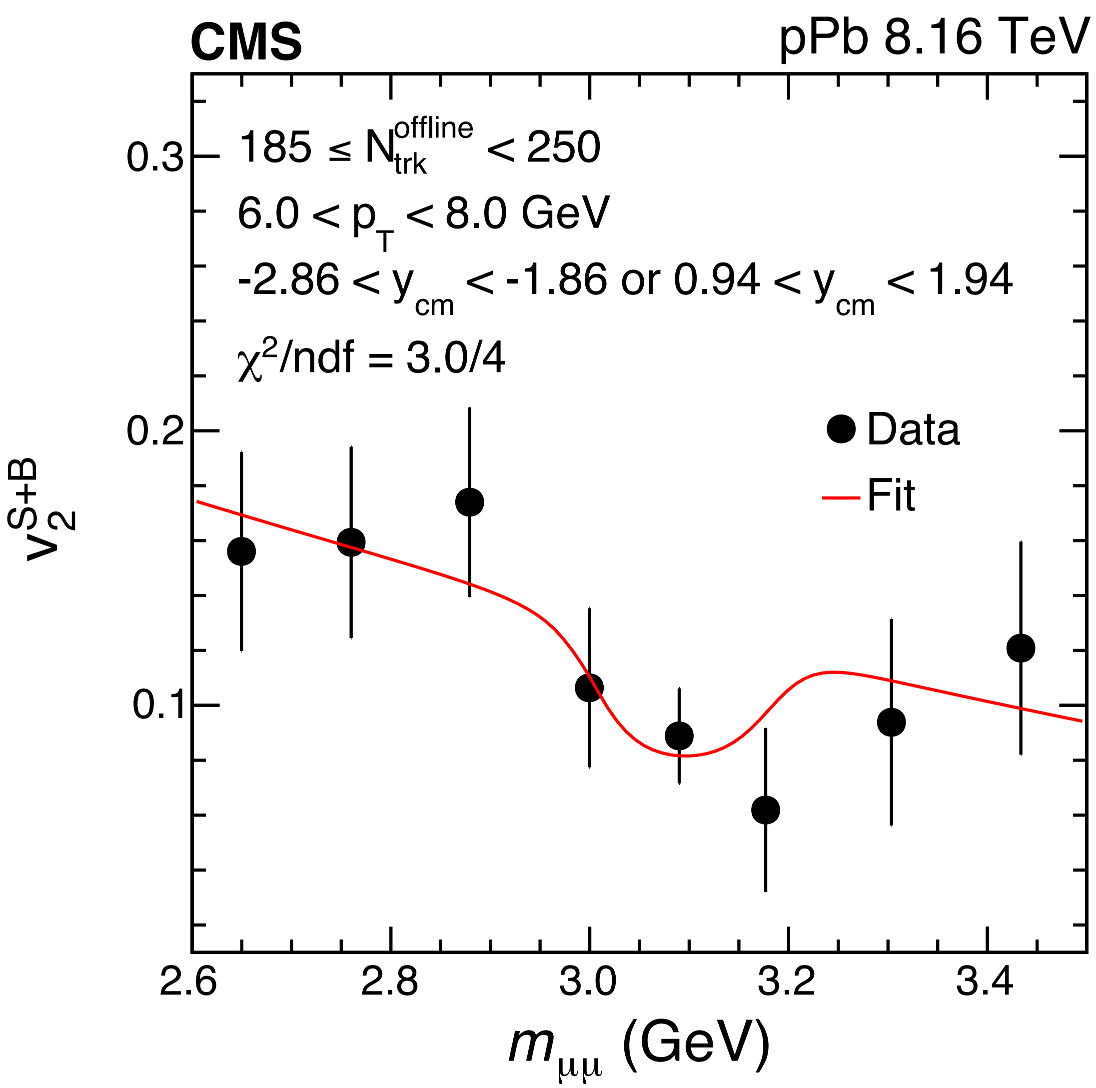


Back up

Simultaneous fitting of J/ψ

PLB 791 (2019) 172





v_2 of J/ψ

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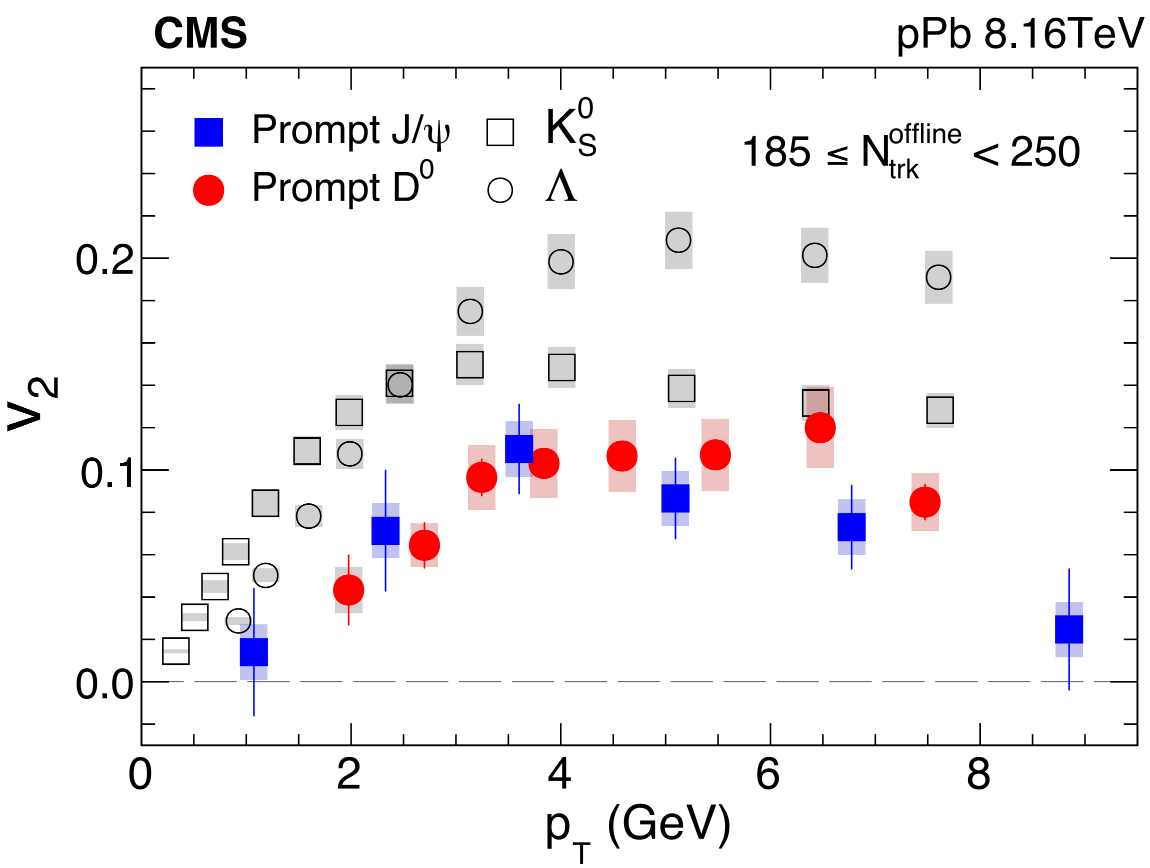

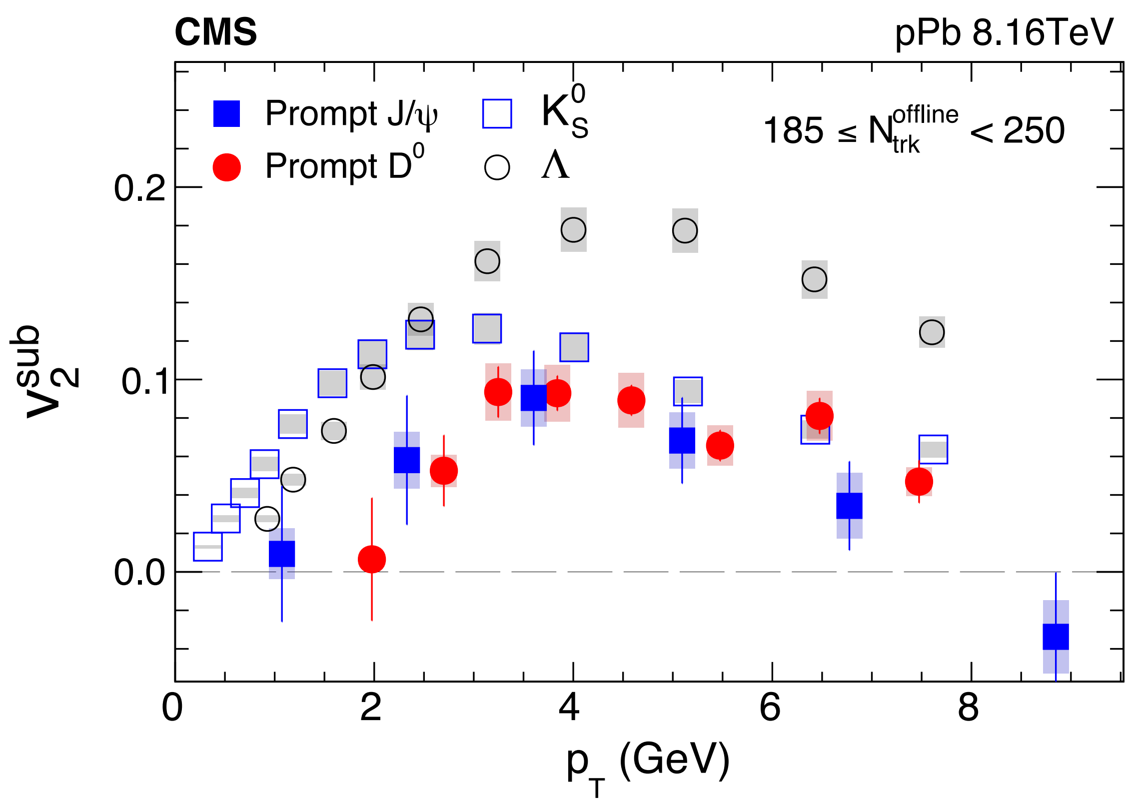

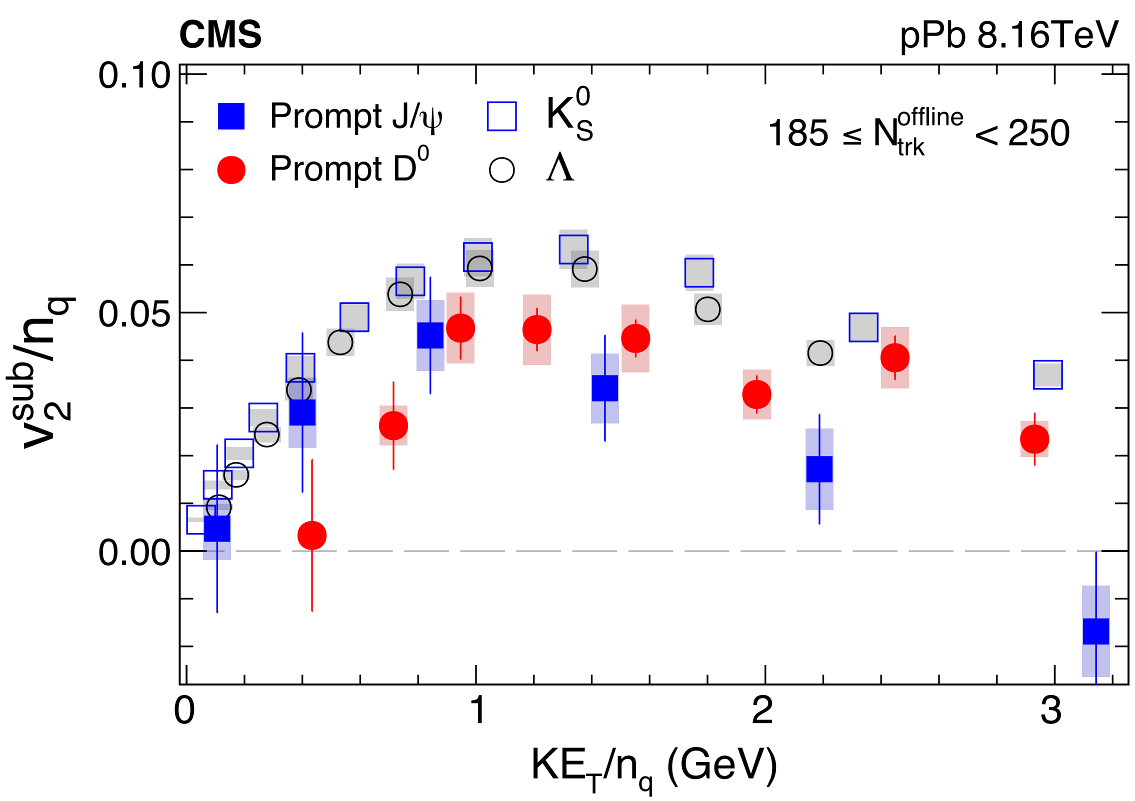

v_2 comparison Υ & J/ψ